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Water vapour detection in hot Jupiters with the CARMENES NIR channel

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Abstract

In this work we use CARMENES near infrared high-resolution ($\mathcal{R}$= 80 400) ground-based observations of hot Jupiters HD 189733 b and HD 209458 b to prove their atmospheres. We have found clear signatures of water vapour in several bands in the 1.0–1.7μm spectral range in both planets as well as evidence of winds in their atmospheres.

1. Introduction

The current interest on radial velocity surveys around M type stars has pushed the development of high-resolution high-stabilized spectrographs in 4-m class telescopes. An example of that is the Calar Alto high-Resolution search for M dwarfs with Exoearths with Near-infrared and optical Échelle Spectrographs (CARMENES, [1]). This instrument offers also the possibility to study the exoatmospheres. That is, the characterization of the evaporating atmospheres of hot Jupiters through the measurements of the helium triplet absorption [2, 3], which has open a new research window, and the detection of water vapour in the hot Jupiter HD 189733 b [4].

In this work we focus on the detection of water vapour in hot Jupiters by using high-resolution transmission spectra in the primary transit and the cross-correlation technique. This technique has proven to be very useful for characterizing the hot Jupiters atmospheres, e.g., [4, 5, 6]. Although the technique is not very sensitive to the atmospheric molecular concentrations, it is one of the few that provide information about the dynamics of their (lower) atmospheres. In particular we analyze the different H_2O NIR (1.0–1.7μm) bands in hot Jupiters HD 189733 b and HD 209458 b by using CARMENES measurements. We also report on the winds derived from the H_2O absorption bands for both exoplanets.

2. Observations and Methods

We have observed two transits of the hot Jupiters HD 189733 b and HD 209458 b for the nights of 7 September 2017 and 6 September 2018, respectively, using CARMENES. The instrument is operating at the 3.5 m telescope at the Calar Alto Observatory. It has two channels, the VIS one covering $\Delta\lambda$ = 520 – 960 nm ($\mathcal{R}$ = 94 600), and the NIR channel covering $\Delta\lambda$ = 960 – 1710 nm in 28 orders ($\mathcal{R}$ = 80 400). Figure 1 shows typical spectra recorded along the transits in the NIR channel. It is noticeable the larger and less variable fluxes measured for the HD 189733 b planet.

We have analysed the spectra by using the cross-correlation technique [5, 6]. Previously we removed the telluric and stellar variations during the observations by using the SYSREM algorithm [7]. The spectra were then cross-correlated with H_2O transmission models generated with the Karlsruhe Optimized and Precise Radiative Transfer Algorithm (KOPRA).

3. Results

The Cross Correlation Functions (CCFs) obtained with the largest significance when including all useful orders are shown in Fig. 2. A clear signal is shown in both exoplanets, although smaller for HD 209458 b, probably caused by the smaller S/N of the measured fluxes (see Fig. 1) and/or the observational conditions (a larger airmass range as well as a more variable precipitable water content). The CCFs obtained covering

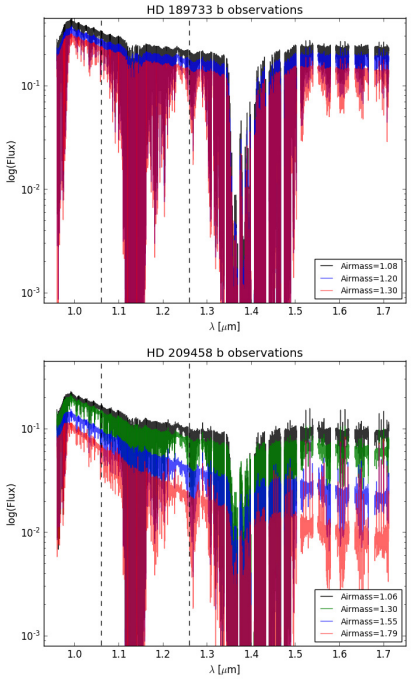

Figure 1: Spectral fluxes (arbitrary units) covering the transits for HD 189733 b (upper panel) and HD 209458 b (lower panel). Airmasses are also given. The dashes lines indicate the limits of the H_2O bands.

the three NIR H_2O bands for both exoplanets will be presented and discussed, as well as the derived atmospheric winds.

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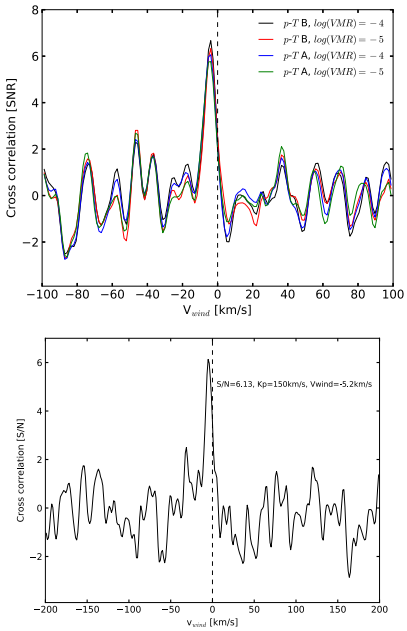

Figure 2: Cross Correlation Functions (CCFs) with the largest significance obtained for all H_2O bands in the 1.0–1.7μm range. Top: for HD 189733 b (after [4]). Bottom: preliminary results obtained for HD 209458 b. Note the different scales.

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